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ON THE FREQUENCY OF ABNORMALITIES IN CONNECTION WITH THE POSTCAVAL VEIN AND ITS TRIBUTARIES IN THE DOMESTIC CAT (*FELIS DOMESTICA*).

C. F. W. McCLURE.

VARIATIONS of the postcaval vein and its tributaries are not of unusual occurrence, as is attested by the considerable literature on this subject. It is also generally conceded that these variations from the normal condition, to whatever cause they may be due, occur with greater frequency among domesticated animals than among those living in the wild state.

The object of the present paper is to emphasize especially the frequency with which such venous abnormalities may occur in a given number of individuals of the domestic cat (*Felis domestica*).

During the last five years the writer has observed that variations of the venous system, of some sort or another, occur with great frequency in the domestic cat; and in 1898–99 twenty-five cats dissected by students in the Princeton Laboratory were more carefully examined for such variations, with the following results:

In only ten of the twenty-five examined was the venous system apparently normal, while in 60 per cent, or in fifteen of the cats, thirty-three distinct abnormalities were met with in connection with the postcava and its tributaries. These, for descriptive purposes, have been grouped in the following table under five types.[1]

The cats in which these abnormalities were found were chosen at random from those brought into the Laboratory and were not, after dissection, selected on account of the abnormalities which they presented.

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[1] The figures represent the actual size of the preparations. The veins are in black and the arteries shaded. The numbering is the same for all of the figures. Many of the smaller arteries and veins have been omitted from the drawings.

Types.	Number of Cases Observed
1. Persistent Posterior Cardinal Veins (*Vv. Cardinales post.*).	
(*a*) Left common iliac vein (*V. iliaca communis sinistra*) absent.	3
(*b*) Left common iliac vein (*V. iliaca communis sinistra*) present.	2
2. The Common Iliac Veins (*V. iliaca communis sinistra* and *dextra*) Unite to Form the Postcaval Vein Opposite the Middle of the Sixth Lumbar Vertebra, which is Considerably Cephalad of the Normal Point of Junction (opposite the posterior half of the seventh). The ilio-lumbar veins also, in each case, open into the right and left common iliacs and not into the common postcava, as is usually the case in the cat.	3
3. The Middle Sacral Vein (*V. sacralis media*) and its Relation to the Veins of the Pelvic Region.	
(*a*) Opens into the right common iliac vein (*V. iliaca communis dextra*)	4
(*b*) Opens into angle of union of two veins which join veins of right and left side, respectively	5
4. Perforation of a Vein by:	
(*a*) An artery	6
(*b*) A nerve	3
5. Double Veins where One is Normally Present	7
	33

Description of the Venous Abnormalities.

1. Persistent Posterior Cardinal Veins (*Vv. Cardinales post.*). — Our knowledge of the development of the postcaval vein and our interpretation of the significance of the persistent double postcaval veins are largely due to Hochstetter,[1] who has shown that these veins are the homologues of the posterior cardinal veins of the embryo and of lower vertebrates.

Wilder and Gage[2] state that double postcaval veins occur in the domestic cat once in about ten cases. This percentage is somewhat less than that found by the writer (20 per cent), but perhaps represents more accurately the conditions commonly met with. In either case the percentage is extremely large when we consider how rarely this abnormality is met with in man.

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[1] Hochstetter. *Anat. Anz.*, Bd. ii, *Morph. Jahrb.*, Bd. xiii, and *Anat. Anz.*, Bd. iii.

[2] *Anatomical Technology*, § 962.

Five cases of persistent posterior cardinal veins were met with by the writer in twenty-five cats examined. In three of these cases the left common iliac vein (*V. iliaca communis sinistra*) was absent, and in two it was present.

(*a*) Persistent Posterior Cardinal Veins. Left Common Iliac Vein (*V. iliaca communis sinistra*) Absent.

The three examples of this type were essentially the same in character and are well represented by Fig. 1.

In each instance the union of the two posterior cardinals (17) with the common postcaval vein (1) took place in the neighborhood of the kidneys. In two instances this union was opposite the third lumbar vertebra, and in one, opposite the fourth. In the former the right renal veins, single in one case and double in the other, opened into the right posterior cardinal; in the latter (Fig. 1) the right renal vein (7) opened into the common postcava (1).

In each instance, as in Fig. 1, the single left renal vein (7) opened into the left posterior cardinal (17).

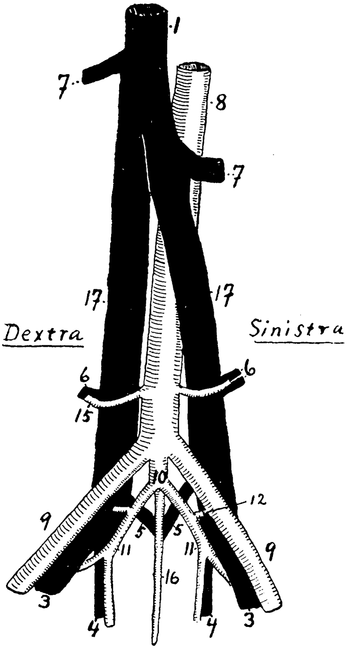

Fig. 1. — Princeton Morphological Museum, No. 601. Ventral aspect. *V. cardinalis dextra* and *sinistra* persistent. *V. iliaca communis sinistra* absent. 1. *Postcava communis*. 3. *V. iliaca externa*. 4. *V. iliaca interna*. 5. *V. sacralis media*. 6. *V. ilio-lumbalis*. 7. *V. renalis*. 8. Aorta. 9. *A. iliaca externa*. 10. *A. iliaca interna communis*. 11. *A. iliaca interna*. 12. *A. hypogastrica*. 15. *A. ilio-lumbalis*. 16. *A. sacralis media*. 17. *V. cardinalis post.*

The middle sacral vein (*V. sacralis media*), Fig. 2 (5), in each of these three cases, was connected with the posterior cardinal veins (17) in a characteristic manner. It opened into the angle of union of two veins which joined, respectively, the right and left posterior cardinal veins (17) at varying distances from the point of union of the external and internal iliac veins.

(*b*) PERSISTENT POSTERIOR CARDINAL VEINS. LEFT COMMON ILIAC VEIN (*V. iliaca communis sinistra*) PRESENT.

Abnormalities of this type have been described as occurring in man, by Cruveilhier, von Gruber, Kollmann,[1] Lobstein, Nicolai, Quain, Wilde, and others.

Kollmann, with whom the writer is fully in accord, states as follows regarding the significance of this type of abnormality: "The significance of this condition can, according to my interpretation, only be as follows: Persistence of both cardinal veins, together with the connecting branch (Verbindungsast)."

By the "Connecting branch" is meant the vessel which is subsequently developed between the veins of the left hind extremity and the right posterior cardinal vein, in correlation with the appearance of the functional kidneys and the atrophy of the distal portion of the left posterior cardinal vein. This vessel becomes the left common iliac vein (*V. iliaca communis sinistra*).

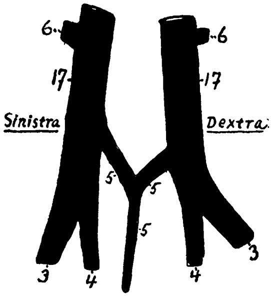

FIG. 2. — Dorsal aspect of Fig. 1. Arteries not indicated. *V. sacralis media* and its connection with *V. cardinalis dextra* and *sinistra*. For reference to numbers, see Fig. 1.

No instance was met with by the writer in which the "Connecting branch" ran in the reverse direction, that is, between the veins of the right hind extremity and the left posterior cardinal vein. Abnormalities of this type, however, have been described by Timmermann, Walter,[2] Walsham, and others, as occurring in man.

Two cases were met with by the writer in which the posterior cardinal veins were persistent, together with the "Connecting branch."

In one (Fig. 3) the union of the two posterior cardinals (17) with the common postcava (1) was opposite the third lumbar vertebra; in the other (Fig. 4) this union was opposite the middle of the sixth lumbar vertebra.

In the first-mentioned case, represented by Fig. 3, where the two posterior cardinals unite with the common postcava opposite the third lumbar vertebra, the middle sacral vein (*V. sacralis media*) opens into the angle of union of two veins which, as in that case previously mentioned (Fig. 2), join, respectively, veins of the right and left side.

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[1] Kollmann gives a very complete bibliography relating to this type of abnormality in Bd. viii of the *Anat. Anz.*, p. 113.

[2] See Kollmann's *Bibliography*.

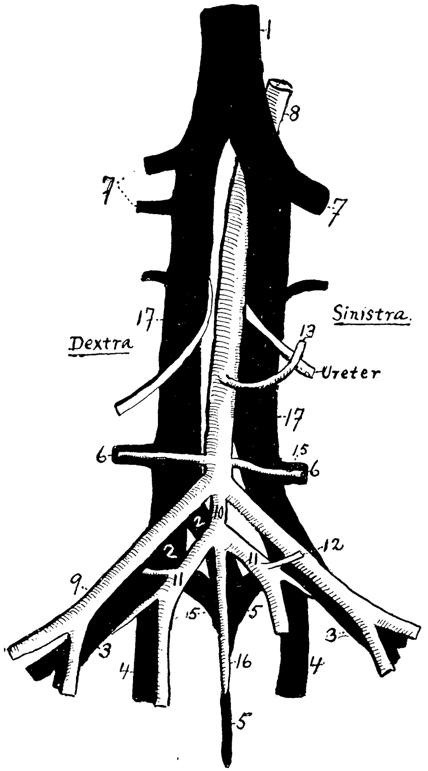

Fig. 3. — Princeton Morphological Museum, No. 602. Ventral aspect. *V. cardinalis dextra* and *sinistra* persistent. *V. iliaca communis sinistra* present. 2. *V. iliaca communis.* 13. *A. mesenterica post.* For remaining numbers, see Fig. 1.

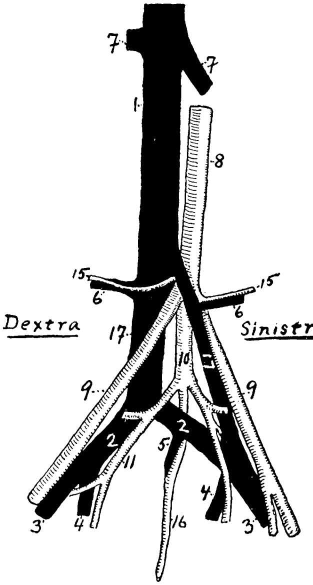

Fig. 4. — Princeton Morphological Museum, No. 603. Ventral aspect. *V. cardinalis sinistra* persistent, *ex parte*. *V. iliaca communis sinistra* present. 2. *V. iliaca communis.* For remaining numbers, see Fig. 1.

In addition to the above mode of union, which seems to be characteristic for the middle sacral vein, whenever both posterior cardinals unite in the neighborhood of the kidneys, the middle sacral vein again opens into the right post-cardinal by an additional vessel. This third vessel, Figs. 3, 5 (2, sinistra), extends between that portion of the middle sacral vein which opens into the left posterior cardinal and the right posterior cardinal vein. It opens into the latter, opposite the point where the right external iliac artery (9), Fig. 3, arises from the aorta. Although the connection of this third vessel with the middle sacral vein is abnormal, its relative position, and especially its connection with the right posterior cardinal at the above-mentioned point, lead the writer to the conclusion that it is the "Connecting branch" (Verbindungsast) which normally grows between the veins of the left hind extremity and the right posterior cardinal vein, in correlation with the appearance of the permanent kidneys and the atrophy of the distal portion of the left posterior cardinal vein. This so-called "Connecting branch," under normal conditions, becomes the left common iliac vein (*V. iliaca communis sinistra*) and returns the blood from the left hind extremity to the postcaval vein. In this particular instance, however, the vein does not connect with the veins of the left hind extremity, but arises from the middle sacral vein by means of two radicles that soon become confluent, Fig. 5 (2, sinistra). The significance of this unusual connection will be spoken of in connection with the following topic.

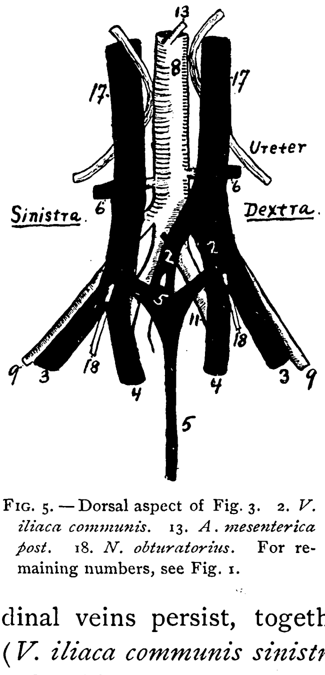

Fig. 5. — Dorsal aspect of Fig. 3. 2. *V. iliaca communis*. 13. *A. mesenterica post.* 18. *N. obturatorius.* For remaining numbers, see Fig. 1.

The second case met with by the writer, in which the posterior cardinal veins persist, together with the "Connecting branch" (*V. iliaca communis sinistra*), is represented by Fig. 4.

In this instance the persistent left posterior cardinal vein (17) unites with the corresponding vein of the right side, opposite the middle of the sixth lumbar vertebra, and not, as in the preceding case, in the region of the kidneys. The left posterior cardinal is also here of less importance physiologically, as is indicated by its relative size, than either the right posterior cardinal or the left common iliac vein (2). It is evident, therefore, that the bulk of the blood from the left hind extremity was carried to the common postcava, chiefly by the left common iliac vein ("Connecting branch"), which is normal in every respect and has, as is usually the case in the cat, the middle sacral vein (5) opening into it. The ilio-lumbar veins (6), which, usually in the cat, open into the common postcava (1), in this instance (Fig. 4), open into separate vessels on the right and left side, respectively. That the vessel (17) on the left side, into which the ilio-lumbar vein (6) opens, is the left posterior cardinal vein and not the so-called "Connecting branch" is evidenced by the fact that the vein in question persists in common with the left common iliac ("Connecting branch"). In addition to this, the left posterior cardinal (17), in Fig. 4, lies ventrad of the aorta at the point where it unites with the corresponding vein of the opposite side, a circumstance characteristic of the left posterior cardinal vein.[1]

The "Connecting branch" is not usually present when the left posterior cardinal persists. Its absence, under these conditions, is undoubtedly due to the circumstance that the left posterior cardinal vein, during all stages of development, continues to collect the blood from the left hind extremity, which makes uncalled for the development of a vessel to share in its function. When for some reason the "Connecting branch" does persist, together with the left posterior cardinal, so far as the writer's experience extends, one vessel is usually developed at the expense of the other. This idea is well borne out by a comparison of Figs. 1, 3, and 4.

In the type of abnormality represented by Fig. 1, the "Connecting branch" is absent, and the left posterior cardinal persists as far forward as the kidneys.

In Fig. 3 the left posterior cardinal is likewise persistent as far forward as the kidneys, but the "Connecting branch," though present, collects little, if any, of the blood from the left hind extremity.

In Fig. 4 both vessels persist, but the left posterior cardinal is insignificant, while the "Connecting branch" is normal in every respect, and undoubtedly, on account of its large relative size, is the chief collector of the blood from the left hind extremity.

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[1] In the preparation represented by Fig. 4 the common internal iliac artery (10) is unusually long. Compare with corresponding arteries in Figs. 1, 3, 6.

The middle sacral vein and the "Connecting branch" (*V. iliaca communis sinistra*) must be developed in close relation with each other, since the former normally opens into the latter. It is not strange, therefore, in one instance (Fig. 3) where the "Connecting branch" is abnormal, that it should arise from the middle sacral vein.

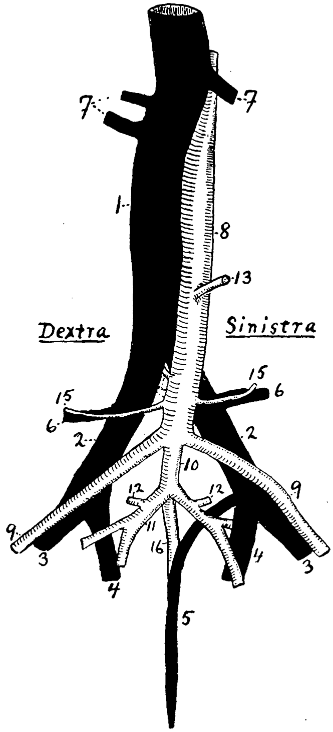

FIG. 6.

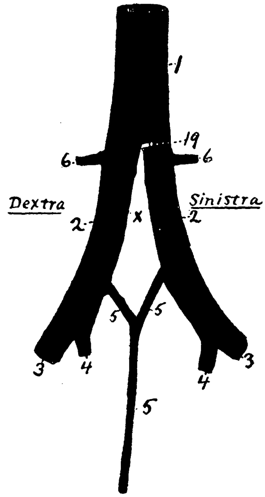

FIG. 7.

FIG. 6. — Princeton Morphological Museum, No. 604. Unusually long *Vv. iliacæ communes* which unite with postcava opposite the middle of the sixth lumbar vertebra. Ventral aspect. 2. *V. iliaca communis.* 13. *A. mesenterica post.* For remaining numbers, see Fig. 1.

FIG. 7. — Princeton Morphological Museum, No. 605. Same as Fig. 6. Ventral aspect. Arteries omitted in the drawing. 19. *A. lumbalis.* X. Opposite origin of *Aa. iliacæ externæ* from aorta. For remaining numbers, see Fig. 1.

2. ON THE PRESENCE OF UNUSUALLY LONG COMMON ILIAC VEINS (*Vv. iliacæ communes*). — The point at which the single postcava joins the right and left common iliac veins is normally, with slight variations, opposite the middle of the seventh lumbar vertebra. In three cats, not including those which possessed well-defined double postcaval veins, the point of union of the two common iliacs with the common postcava was found to be opposite the middle of the sixth lumbar vertebra,

which is considerably cephalad of the normal point, and to result in relatively long common iliac veins (2), Figs. 6, 7.

The writer was at first inclined to regard these three cases as instances in which the posterior division of the left posterior cardinal vein, instead of the "Connecting branch," persists as the functional left common iliac vein, and for the following reasons:

1. Because in one instance (Fig. 7) the middle sacral vein (5) opens into the angle of union of two veins, as in those cases in which both posterior cardinal veins persist (Fig. 1).

2. Because the left ilio-lumbar vein (6), in all three cases, opens into the left common iliac (2) and not into the common postcava (1), as is normally the case in the cat. (See Figs. 6, 7.)

3. Because the functional left common iliac vein (2), in all three cases, unites with the corresponding vein of the opposite side in front of the middle of the sixth lumbar vertebra and, in this respect, resembles the left posterior cardinal vein (17) in Fig. 4, which persists there, in addition to a left common iliac vein ("Connecting branch"). In other words, if the left common iliac vein (2) were absent in Fig. 4, the latter would resemble, so far as the veins are concerned, the conditions met with in Fig. 6.

One marked difference exists, however, between the relative position of the left common iliac (2) in the three cases cited above and that of the left posterior cardinal vein (17) in Fig. 4. In the latter the vein lies ventrad of the aorta, the position it should normally assume were the vessel a persistent cardinal vein. In the three other cases, of which Fig. 6 is an example, the aorta (8) lies ventrad of the vein, which should not be its position unless a transposition of the vessel has taken place, a circumstance incapable of proof. Whatever the significance of this abnormality may be, it is certainly worthy of mention, for it further emphasizes the fact that variations of the postcaval vein and its tributaries are of unusual frequency in the cat.

3. THE MIDDLE SACRAL VEIN (*V. sacralis media*) AND ITS RELATIONS TO THE VEINS OF THE PELVIC REGION. — Much has already been said concerning this vein, but its variations are so pronounced, that it seems best to specify them more in detail.

The middle sacral vein usually opens into the left common iliac, and this was found to be the case by the writer in 60 per cent of the cats examined. In some instances this vein (5) was found to open into the left common iliac (2), near the point of union of the external and internal iliac veins (3 and 4), Fig. 6. In other instances its connection with the left common iliac was somewhat cephalad of this point.

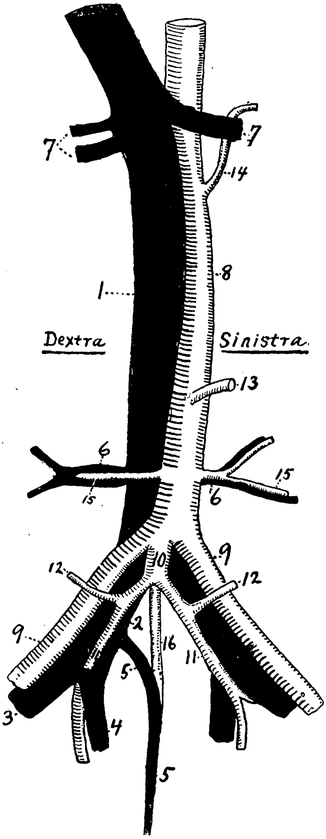

FIG. 8. — Princeton Morphological Museum, No. 606. Perforation of *V. iliaca communis dextra* by *A. iliaca interna dextra.* Ventral aspect. 2. *V. iliaca communis.* 13. *A. mesenterica post.* 14. *A. renalis.* For remaining numbers, see Fig. 1.

In four cats, or 16 per cent of those examined, the middle sacral vein (5) opened into the right common iliac (2), Fig. 8. This was the case with one of those preparations in which the common iliac veins were unusually long and joined the single postcava opposite the sixth lumbar vertebra.

In five cats, or 20 per cent of those examined, the middle sacral vein (5) opened into the angle of union of two veins which joined a vein of the right and left side, respectively (Figs. 1, 3, 7).

4. ON THE PRESENCE OF FORAMINA IN VEINS THROUGH WHICH ARTERIES AND NERVES PASS. — (*a*) Six cases were met by the writer in which a vein presented a completely formed foramen through which an artery passed. In four of these cases the internal iliac artery passed through a foramen in the common iliac vein. In the two remaining instances a lumbar artery passed dorsad through a foramen in the postcaval vein.

Two cases were met with in which the right internal iliac artery (11) passed through a foramen in the right common iliac vein (2), as represented by Fig. 8.

The foramen, which, in both cases, was situated near the juncture of the external and internal iliac veins, was complete, so that the artery could be dissected away from the vein without injuring the latter. After passing through the foramen the artery naturally lies dorsad of the vein, but in its subsequent course assumes its usual position at the side of the vein.

Two cases were met with, in which the left internal iliac artery passed through a foramen in the left common iliac vein. Since there is no essential difference between any of these four cases, so far as the character and relative position of the foramina are concerned, Fig. 8 will serve as a description for all.

Treadwell[1] has described an abnormality as occurring in the cat somewhat similar to these four cases described above, but on account of the poor condition of his preparation, he was unable to locate accurately the exact position of the foramen. An examination of his figure leads the writer to the conclusion that his preparation is similar, in every respect, to that represented above by my Fig. 8.

The two cases in which a lumbar artery passed through a foramen in the postcaval vein resemble those mentioned above, so far as the completeness of the foramina is concerned, and, therefore, need no further mention. It is interesting to note, however, that in each instance the vein was penetrated by the same lumbar artery, the artery situated just cephalad of the ilio-lumbar artery.

(*b*) Foramina, when present, were not exclusively connected with the transference of arteries. In three cats both obturator nerves (18), Fig. 5, were found to pass through foramina situated at the point where the external and internal iliac veins unite.

The foramina in each instance were complete, and, as in the case of the arteries, the nerves were easily dissected away without injuring the veins.[2]

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[1] *Anat. Anz.*, Bd. xi, p. 717.

[2] Ogle (*Journ. of Anat. and Phys.*, vol. xxix) describes a case as occurring in man, in which the left hypoglossal nerve pierced the wall of the left vertebral artery.

It is well known that the perforation of a vein by an artery or nerve is not, by itself, of unusual occurrence, but that it should occur with such frequency in the domestic cat, and in connection with so many other abnormalities, is deemed by the writer as worthy of mention, as it further emphasizes the unstable condition of the veins in the lumbar and pelvic regions.

Whatever the cause may be which has produced this type of abnormality, it is probably the same for both nerve and artery, and, Treadwell says, "may be referred back to the origin of the vessels in the embryo, where an interference between the formative cells of the artery and those of the vein has resulted in a penetration of one by the other."

It seems worthy of emphasis to note, in this connection, that in each instance it is the vein which is perforated and never the artery.

5. DOUBLE VEINS WHERE ONE IS NORMALLY PRESENT. — This type of abnormality is, likewise, of fairly common occurrence, and is only mentioned to further emphasize the frequency of venous abnormalities in the regions in question.

In seven instances veins which are usually single were paired, and with one exception, Fig. 1 (left double ilio-lumbar veins, 6), this duplicity occurred in connection with the veins of the right side.

Four of the above-mentioned cases refer to the renal veins and three to the ilio-lumbar.

In one case, Fig. 8 (6), the right ilio-lumbar vein (*V. ilio-lumbalis dextra*) opened into the postcava (1) by two veins, but laterad of the postcava the two veins were fused together, and through the cleft thus formed the right ilio-lumbar artery (15) passed.

The question might be asked, — Is the manner in which this cleft is formed, in any sense, comparable with that of the foramina mentioned above in connection with the postcava and common iliac veins?

It seems probable to the writer, since the foramina in the common iliac veins are located near the point of union of two veins, that these foramina may have been formed as the result of a secondary union of the veins behind the artery or nerve which passes between them.

As previously stated, the lumbar artery, which, in two cases, was found to penetrate the postcava, was the one situated just anterior to the ilio-lumbar veins. In the case represented by Fig. 7, this artery (19) lies between the common iliac veins, near their point of union. If in this instance the veins should fuse behind the artery, a foramen would be formed which resembles in every respect the two met with in the postcava.

So far as could be ascertained by the writer, the number of abnormalities of the arterial system, in general, was small. This was also the case with the veins of the neck and fore-limb regions, which in no way approximated those found in connection with the postcava and its tributaries.

The arterial abnormalities were chiefly confined to the ilio-lumbar and iliac arteries, an example of the latter being figured below (Fig. 9).

One conclusion which may be drawn from a perusal of the preceding pages is that, in the cat, the veins of the lumbar and pelvic regions appear to be more liable to variation than those of any other region of the body. Whether this variation may be the result, as some might maintain in virtue of the shifting character of the lumbar vertebra, of a general instability of this region is an open question.

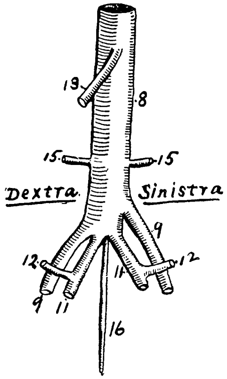

Fig. 9. — Princeton Morphological Museum, No. 607. Abnormal mode of origin of *Aa. iliacæ.* Ventral aspect. 13. *A. mesenterica post.* For remaining numbers, see Fig. 1.

The greater frequency, however, with which abnormalities of the postcava and its tributaries occur, whatever the causes may be which produce them, may possibly be explained on the following grounds: The veins of the lumbar and pelvic regions possess a marked primitive arrangement in the embryo, which differs from that of the adult. In the transition from the embryonic to the adult condition, the veins, on account of the changes which they have to undergo, thus readily lend themselves to variations when, for any cause, their normal development is interrupted.

It is without the purpose of this paper to discuss the causes which are responsible for the production of venous abnormalities. It seems fair to assume, however, that any cause which may disturb the character of the normal stimuli that control the development of an organism may correspondingly influence the veins, by either arresting, accelerating, or even annulling their development.

Such causes, the effects of which undoubtedly influence these normal stimuli, must be numerous, and among others the following might be mentioned: Domestication, inbreeding, disease, drugs, and shock.

It seems, therefore, reasonable to assume that breeding experiments, carried out on these lines, might give us some clue as to the direct causes, as well as the relation of cause and effect, which are responsible for the production of abnormalities of the vascular system.

PRINCETON, N. J., January, 1900.